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LABORATORIES **BILLINGS, MONTANA**

MONTANA STATE HIGHWAY COMMISSION
LEGAL DEPARTMENT

CLAY INVESTIGATION

LOVELL CLAY PRODUCTS PROPERTY
PROJECT NO. I-90-8-23
LAB NO. 6806

MAY 1965

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LEGAL DEPARTMENT

MONTANA STATE HIGHWAY COMMISSION
HELENA, MONTANA

*CLAY INVESTIGATION

LOVELL CLAY PRODUCTS PROPERTY
BILLINGS, MONTANA
PROJECT NO. I-90-8-23
LAB NO. 6806

BY

JOHN G. YAPUNCICH, CONSULTING CHEMIST
(John G.)
YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA

The property consists of 224,659 cubic yards of clay suitable for the manufacture of brick and tile.

MAY 1965

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SUMMARY

A technical investigation of the Lovell Clay Products property, condemned for new highway construction, was completed and the detailed information presented in this report.

Briefly, the data shows the following pertinent facts:

(1) All of the property consists of useable clay.

(2) Total volume of clay present is 224,659 cubic yards of which 63,158 cubic yards is below the water table and 161,501 cubic yards is above the water table.

(3) The clay makes a good quality brick suitable for the manufacture of common brick, face brick, structural tile, or drain tile. By blending with other clays it could be used for the production of sewer pipe.

INTRODUCTION

This report presents an investigation of the Lovell Clay Products property, Billings, Montana, which was condemned for the purpose of new highway construction. The investigation was made to determine the volume of clay material present and its suitability for making a quality brick product.

Authorization for this investigation was given by Lewis M. Chittim, Right-of-Way Division, Montana State Highway Department for the Montana State Highway Commission, Legal Department.

The investigation was conducted in the following manner:

(1) Five test holes were drilled on the property to gravel and samples taken per foot.

(2) Property was surveyed and volume of clay determined.

(3) Laboratory tests and kiln firing tests were made on composite samples from test holes to determine soil classification and type and quality of brick that could be manufactured from the clay.

No attempt was made in this study to assign a value to the clay material.

The highway department attempted to buy the property from Lovell Clay Products through negotiations but failed to come to an agreement. Lovell Clay Products assigned a definite value to the clay material on the property in addition to the regular value as commercial property. The Right-of-Way division questioned the value and amount of clay material present and requested information as to the volume and quality of clay on the property in order to make an intelligent appraisal.

FIELD SAMPLING

Five test holes were drilled with a four-inch auger to gravel by Montana State Highway Department and supervised by the Yapuncich, Sanderson & Brown Laboratories.

Samples were taken at one-foot intervals for laboratory testing and examination. At the same time five-foot composite samples were collected for Lovell Clay Products Company, Inc.

The holes are numbered one through five and are located on the property so as to represent the area. The map attached to this report shows the property and location of the test holes.

The following table gives the location of test holes, collar elevation, clay thickness and depth to water level.

HOLE NO.	LOCATION	COLLAR ELEVATION FEET	CLAY THICKNESS FEET	DEPTH TO WATER LEVEL, FEET
1	St. 997+00, C-L Median	3131.40	38	29.5
2	30' Rt. St. 994+40' C-L Median	3133.84	41	30.4
3	100' Lt. 992+00 C-L Median	3126.52	35	26.1*
4	St. 996+00 C-L North Frontage Road	3115.40	22.5	12.2
5	115' Rt. 996+00 C-L Median	3137.08	42.5	34.6

* Next day 30.6' to cave-in with 3' water on top = 27.6' to water level.

NOTE: 1. Elev. ref. point = iron pin on St. 995+00 C-L Median = 3133.30'

2. All holes through 1' gravel except No. 1, in which auger broke at 38' and therefore assumed gravel at this point.

CLAY VOLUME DATA

The Lovell Clay Products property under investigation was surveyed by the Montana State Highway Department to get the area involved and elevations. With this information and thickness of the clay body to the water table and below the water table to gravel, the volume of clay was calculated by the Highway Department design engineer. The volume calculations and the cross-sectional areas as done by the highway department were checked by the laboratory.

The volume of clay is given in two sections, that above the water table and that below the water table. This was done for the convenience of evaluators in determining the value of the clay property. It was assumed that the clay above the water table would cost less to excavate. The wet clay in the water table could not be excavated directly but would require the expense of draining and drying. Therefore, a lower value could be given the wet clay by the appraisers.

The volume calculations data are given on Pages 26 and 27. The cross-sectional areas were drawn on large linear graph paper, 2 ft. by up to 4 ft. in length. These drawings are not included in this report. The drawings were considered too large and bulky to reproduce and include with the report. The original drawings are being filed and saved by the laboratory for future reference.

The volume of clay calculated to be present on the Lovell Clay Products property under investigation is given below:

Clay above water table	161,501 Cubic Yards
Clay below water table	63,158 Cubic Yards
Total volume of Clay	224,659 Cubic Yards

LABORATORY DATA

1. Preparation of Samples.

Samples were dried at 200°F, crushed and put through a pulverizer in order to pass an 8-mesh sieve. The pulverizer did not breakdown grain size of the clay and sand particles. To reduce the number of samples to be tested and because of the similarity of the material, composite samples were made representing five foot sections. In addition, for firing tests a composite sample was made of test holes 1, 2, 3 & 5 (originally numbered as 2, 5, 8 & 10) and one of test hole No. 4 (old number 14).

2. Laboratory Examination of Samples.

A microscopic examination of all samples was made by the Yapuncich, Sanderson & Brown Laboratories and a descriptive log made of each test hole. These logs are shown on pages 11 through 15. A log of the test holes as prepared by the Montana State Highway Department Soils Engineer, during drilling operations, is shown on pages 16 through 20.

The material is clay with varying amounts of silt and fine sand. The upper portion of the test holes appeared sandy and silty whereas the bottom portion appeared to be a heavier clay. All of the material was very fine. The upper part was dry and appeared quite sandy but on wetting, the material took on properties of a good clay. The wet portion appeared to be a normal heavy clay.

3. Sand Content

Sand content of the samples was made by Yapuncich, Sanderson & Brown Laboratories in order to differentiate the sand section from the clay. However, no apparent sand section not suitable for brick manufacture was noted, even though the upper dry portion looked sandy. The sand content is listed in the tables given on pages 21 through 25.

The sand content varied from a low of 4.2% for heavy clay to a high of 31.5% for the silty, sandy clay. According to ceramic literature, sand is added to clay to improve drying and shrinkage properties. This clay material is considered high in sand content but is still suitable clay for manufacturing brick and useful for blending purposes as is pointed out in the section under firing tests later in this report.

3. Sand Content cont.

The sand content was made by washing a known weight of sample through a 200 mesh screen, drying and weighing the fine sand retained in the screen.

4. Plasticity Index and Soil Type

Although by visual inspection and sense of feel the material appeared to be clay, further laboratory tests were made to definitely classify the material as a clay. These soil tests, the liquid limit and plastic limit, were made by the Montana State Highway Department Materials Laboratory. From this data the plasticity index and soil type was determined. This data is presented in the tables given on pages 21 through 25 .

The results of these tests show that the material is a clay.

5. Kiln Firing Tests

Suitability of clays for manufacture of good quality brick and tile cannot be determined by microscopic examination and laboratory soil tests alone. The clay samples have to be subjected to drying and kiln tests in which test brick bars are made simulating brick manufacturing conditions. Before firing the extruded brick bar is dried. During this drying period the test bar should not crack, warp or shrink excessively to make a good brick. Then on firing, the bar should have a good color, hardness of steel, low absorption and shrinkage.

Composite samples were sent to W. O. Brandt, Ceramic Engineer, Denver, Colorado, for kiln firing tests and his test report is included immediately following this page.

The firing test report is complete and self-explanatory. These tests show that the clay material from Lovell Clay Products property is suitable with or without other clays for the manufacture of brick, tile and sewer pipe.

WILLIAM O. BRANDT
CERAMIC ENGINEER

PHONE: Area 303
757-1730

1350 SOUTH MONROE STREET
DENVER, COLORADO 80210

May 26, 1965

TESTS OF CLAY SAMPLES SUBMITTED UNDER NO. 6806 BY YAPUNCICH, SANDERSON, AND BROWN LABORATORIES, BILLINGS, MONTANA

Nine samples of clay were received May 21, 1965, in quantities of approximately ten pounds each. All had been pulverized rather finely. Sizing was not checked but appeared to be about -40 mesh. Testing was desired to determine suitability for use in structural clay products.

Procedures

Samples were hand mixed with tap water to a desirable workability, and extruded from a Davis-Brown Laboratory Deairing Auger Machine into test bars approximately 1 1/8 inches square and 5 inches long. In order to assure uniformity and thorough mixing all material was run through the machine twice. Vacuum of 25.5 inches was maintained in the machine when extruding. After extrusion, bars were air dried in the laboratory.

Three firings of bars were made in a D.F.C.-Dickinson No. 26H electric kiln equipped with a Wheelco potentiometric pyrometer controller. The kiln was held at 200 - 300° F. for two hours to evaporate all water remaining in the bars, then advanced to the peak temperature in approximately 5 hours and held at that temperature for 1½ hours. An oxidizing condition was maintained throughout the firing.

Shrinkage of the test bars was determined by impressing them with a 4.00 inch marking gauge immediately after extrusion and measuring changes in length after drying and firing with a rule graduated in fiftieths of an inch.

For the purpose of expediting this work, dry strength was judged by experience and finger pressure required to break off corners and edges; fired strength was judged by resistance to cutting by knife point and by ring when bars were struck together.

Data is recorded in Appendix A.

Results

All samples were plastic enough to extrude satisfactorily. Relative plasticities are recorded in the appendix. No difficulty occurred in drying the test bars. (Normally bars will crack and break up if the material being tested is too difficult to dry for use in commercial products.) Drying shrinkage is 1-2% higher than usually desired for structural clay products, but this is probably due to the fineness of the samples. All samples had good dry strength.

No difficulties were experienced in firing. All samples were greatly underfired at 1800° F. and slightly underfired at 1900° F. Colors were light red at both temperatures. Bars were just less than steel hard at 1900°. A slight decrease in shrinkage measurement between dried and 1800° F. fired test bars was unusual and indicates a relatively high content of fine silica sand or silt in these materials.

At 2000° F. colors were good, ranging from bright red for samples from upper levels of holes 2, 5, 8, and 10 to slightly

brownish red for lower level samples of these holes and the composites of these holes and hole 14. Strengths were good as shown by steel hardness and ring of the test bars. Absorptions were in a satisfactory range for use in commercial products.

A moderate amount of white scumming occurred on samples from the lower levels, but it was not excessive and in use could be controlled by usual additions of barium carbonate used in clay products.

Conclusions

The materials submitted are clays of suitable quality to be used with or without other clays for the manufacture of common brick, face brick, structural tile, or drain tile. By blending with other clays, they could be used for the manufacture of sewer pipe.

Although the fine sand content is high in all the samples, they had sufficient plasticity to extrude well. This sand content would make them very useful for blending purposes.

William O. Brandt
Colo. Reg. No. 3444

APPENDIX A

Sample Well Holes	Sample Sections	Plasticity	Water of Plasticity(1)	Dry Shrinkage(2)	Total Fired Shrinkage 1800°	Total Fired Shrinkage 1900°	Total Fired Shrinkage 2000°	Absorption, Fired 2000°(3)
Nos. 2, 5, 8, 10 Composites	0 -- 5'	Fair	18.0%	6.8%	6.7%	7.0%	9.2%	11.8%
	5 - 10'	Fair	18.3	6.7	6.7	7.2	9.0	11.5
	10 - 15'	Good	20.2	7.5	6.1	6.5	10.3	9.3
	15 - 20'	Very Good	18.3	7.0	6.3	7.5	8.9	11.8
	20 - 25'	Very Good	22.4	8.5	7.7	n.d.	10.5	12.2
	25 - 30'	Good	23.0	8.6	7.5	9.5	12.0	8.4
	30 - 35'	Good	22.8	8.9	7.3	9.3	12.0	8.8
	35 - 42'	Fair	20.9	8.3	7.0	9.0	11.7	6.6
	Total Composite 0 - 42'	Good	19.2	7.8	6.6	8.3	10.5	10.0
No. 14	Composite 0 - 22.5'	Good	20.9	8.3	6.7	8.6	11.3	8.5

Note: (1) Water of Plasticity is water requirement, in percent of dry clay weight, required for extrusion.

(2) All shrinkage data is in percent of plastic length.

(3) Absorption determined by placing bars in vacuum chamber, evacuating to 25 in. Hg, and then admitting water and then atmospheric pressure for 15 minutes. Equivalent to A.S.T.M. five-hour water boiling test.

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA

LAB NO. 6806

LABORATORY DESCRIPTION OF SAMPLES FROM HOLE NO. 1

PROJECT I-90-8-23
STATION 997+00 ON CENTER LINE MEDIAN
SAMPLED MAY 7, 1965
LOVELL CLAY PRODUCTS PROPERTY
MICROSCOPIC EXAMINATION

DEPTH, FT.	DESCRIPTION
1	Brown clay, slightly sandy & silty
2	Fine sand, tan color, silty with clay particles
3	Fine sand, tan color with clay particles
4	Fine sand, tan color with clay particles
5	Tan sand, medium to silty with clay particles
6	Tan sand, medium to very fine clay particles
7	Tan sand, medium to very fine clay particles
8	Tan sand, medium to very fine clay particles
9	Tan sand, medium to silty with clay particles
10	Tan sand, clayey
11	Tan sand, clayey
12	Tan sand, medium to very fine, clayey
13	Silty clay
14	Silty clay
15	Silty clay
16	Silty clay
17	Sand, clayey
18	Clay, silty
19	Clay, silty
20	Clay, silty
21	Sand, clayey
22	Clay, silty
23	Clay, silty
24	Clay, silty
25	Clay, silty
26	Clay, silty
27	Sand, clayey
28	Clay, silty
29	Clay, silty
30	Clay, silty
31	Clay, silty
32	Silty clay
33	Silty clay
34	Silty clay
35	Silty clay
36	Silty clay
37	Silty clay
38	Clay

NOTE: Auger broke at 38', assumed gravel at this point.

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA

LAB NO. 6806

LABORATORY DESCRIPTION OF SAMPLES FROM HOLE NO. 2

PROJECT I-90-8(23)U-2
STATION 30' RIGHT OF 994+40 ON CENTER LINE MEDIAN
SAMPLED MAY 11, 1965
LOVELL CLAY PRODUCTS PROPERTY
MICROSCOPIC EXAMINATION

DEPTH, FT.	DESCRIPTION
1	Silty clay
2	Very fine sand with clay particles
3	Fine to silty sand with clay particles
4	Fine to silty sand with clay particles
5	Fine to silty sand with clay particles
6	Fine to silty sand with clay particles
7	Fine to silty sand with clay particles
8	Fine to silty sand with clay particles
9	Very fine to silty sand, clay present
10	Very fine to silty sand, clay present
11	Very fine to silty sand, clay present
12	Sandy clay
13	Sandy clay
14	Fine to silty sand, clayey
15	Sandy clay
16	Silty clay
17	Silty clay
18	Sandy clay
19	Fine to silty sand, clayey
20	Sandy clay
21	Fine to silty sand, clayey
22	Sandy clay
23	Silty clay
24	Very sandy clay
25	Silty clay
26	Silty clay
27	Silty clay
28	Silty clay
29	Silty clay
30	Silty clay
31	Silty clay
32	Silty clay
33	Silty clay
34	Silty clay
35	Silty clay
36	Fine to silty sand, clayey
37	Fine to silty sand, clayey
38	Silty clay
39	Silty clay
40	Silty clay
41	Silty clay
42	Very fine to silty clay
43	Gravel, clayey

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA

LAB NO. 6806

LABORATORY DESCRIPTION OF SAMPLES FROM HOLE NO. 3

PROJECT I-90-8(23)U-2
STATION 100' LEFT OF 992+00 ON CENTER LINE OF MEDIAN
SAMPLED MAY 12, 1965
LOVELL CLAY PRODUCTS PROPERTY
MICROSCOPIC EXAMINATION

DEPTH, FT.	DESCRIPTION
1	Very sandy clay
2	Fine to silty sand with clay particles
3	Fine to silty sand with clay particles
4	Fine to silty sand with clay particles
5	Fine to silty sand with clay particles
6	Fine to silty sand with clay particles
7	Fine to silty sand with clay particles
8	Fine to silty sand with clay particles
9	Fine to silty sand with clay particles
10	Fine to silty sand with clay particles
11	Clayey sand
12	Silty clay
13	Silty clay
14	Clayey sand
15	Silty clay
16	Clayey sand
17	Clayey sand
18	Clayey sand
19	Clayey sand
20	Silty clay
21	Silty clay
22	Silty clay
23	Silty clay
24	Very sandy clay
25	Very sandy clay
26	Silty clay
27	Silty clay
28	Silty clay
29	Silty clay
30	Silty clay
31	Silty clay
32	Silty clay
33	Clayey sand
34	Clayey sand
35	Clayey Sand
36	Gravel

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA
LAB NO. 6806

LABORATORY DESCRIPTION OF SAMPLES FROM HOLE NO. 4

PROJECT I-90-8(23)U-2
STATION 996+00 ON CENTER LINE OF N.F. ROAD
SAMPLED MAY 13, 1965
LOVELL CLAY PRODUCTS PROPERTY
MICROSCOPIC EXAMINATION

DEPTH, FT.	DESCRIPTION
1	Fine to silty sand with clay particles
2	Fine to silty sand with clay particles
3	Sandy clay
4	Sandy clay
5	Silty clay
6	Clayey sand
7	Silty clay
8	Silty clay
9	Silty clay
10	Very sandy clay
11	Very sandy clay
12	Silty clay
13	Silty clay
14	Silty clay
15	Silty clay
16	Silty clay
17	Silty clay
18	Silty clay
19	Silty clay
20	Silty clay
21	Silty clay
22	Very sandy clay
22-22½	Very sandy clay
22½-23½	Sandy gravel

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA

LAB NO. 6806

LABORATORY DESCRIPTION OF SAMPLES FROM HOLE NO. 5

PROJECT I-90-8(23)U-2
STATION 115' RIGHT OF 996+00 ON CENTER LINE
SAMPLED MAY 13, 14, 1965
LOVELL CLAY PRODUCTS PROPERTY
MICROSCOPIC EXAMINATION

DEPTH, FT.	DESCRIPTION
1	Sandy, silty clay
2	Clayey sand
3	Very fine sand with clay particles
4	Very fine sand with clay particles
5	Very fine sand with clay particles
6	Very fine sand with clay particles
7	Very fine sand with clay particles
8	Very fine sand with clay particles
9	Very fine sand with clay particles
10	Very fine sand with clay particles
11	Very fine sand with clay particles
12	Silty clay
13	Silty clay
14	Clayey sand
15	Clayey sand
16	Silty clay
17	Silty clay
18	Silty clay
19	Silty clay
20	Very sandy clay
21	Very sandy clay
22	Silty clay
23	Silty clay
24	Silty clay
25	Silty clay
26	Silty clay
27	Silty clay
28	Silty clay
29	Silty clay
30	Silty clay
31	Clayey sand
32	Clayey sand
33	Clayey sand
34	Clayey sand
35	Silty clay
36	Silty clay
37	Silty clay
38	Clayey sand
39	Clayey sand
40	Silty clay
41	Silty clay
42	Fine to silty sand with clay particles
42.5	Fine to silty sand with clay particles
43.4	Gravel

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 474 Project No. I-90-8(23)U-2 Hole No. 1
Termini Billings Date Taken May 7, 1965
Location Sta. 997+00 on ℄ median Structure Lovell Clay Pit Prospect Hole
Party Chief Cook Others Green & Etzold

Stratification			Description of Materials	Casing		
Elev.	Depth	Legend	Type, Color & Consistency	Blows	Penet-ration	Rotary Drilling
3131.40 ft.			Tan sandy silt.			
	11.5		Dark brown clay with traces of sand.			
	23.0		Very moist.			
	28.0		Water (Hole caves)			
			Stiff dark brown clay.			
	37.5		Very stiff dark brown clay; bottomed hole in this material because of broken Iwan auger.			

Miscellaneous Data
Depth of Hole 37.5 ft.
Rock
Wt. of Hammer
Average Fall of Hammer
Elev. of Ground Water. 29.5 ft.

Remarks

Hole was bored with 4" Iwan auger in intervals of 0.5' and 1.0', dependent on expansion of material in auger.

Samples in 1.0 ft. intervals were bagged in Poly bags and were given to Yapuncich, Sanderson & Brown Lab for analysis,

Composite samples in 5.0' intervals were taken by Lovell Clay Products representative.

Elevation Reference Point: Iron pin at Sta 995+00 on ℄ Median.

Elevation 3133.30 ft.

BM	BS	HI	FS	Elev.
3133.30	6.22	3139.52	8.40	3131.12
	8.40	3139.52	6.46	3133.06
	5.42	3138.30	6.90	3131.40

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 475 Project No. I-90-8(23)U-2 Hole No. 2
Termini Billings Date Taken May 11, 1965
Location 30' Rt. of Sta. 994+40 ℄ Median Structure Lovell Clay Prospect Holes
Party Chief Cook Others Green & Etzold

Miscellaneous Data
Depth of Hole 42.7 ft.
Rock
Wt. of Hammer 140#
Average Fall of Hammer 30"
Elev. of Ground Water. 30.4 ft.

Stratification *Elev.*	*Depth*	*Legend*	*Description of Materials* *Type, Color & Consistency*
3133.84 ft.			Brown sandy silt.
	7.0		Brown silty sand.
	10.0		Traces of brown clay, changing to brown sandy silt.
	15.0		Dark brown silty clay.
	21.0		Moist silty clay.
	30.0		Very moist, hole caves at 31.0 ft.
	36.0		Strata of wet sand.
	37.0		Stiff, dark brown clay.
	41.0		Thin strata light tan clay.
	42.7		Bottomed hole in hard gravel.

Remarks

Holes was bored with 4" Iwan Auger in 0.5' and and 1.0' intervals, depending upon expansion of the material in the auger.

Samples in 1.0' intervals were bagged in Poly bags and were given to Yapuncich, Sanderson & Brown Lab. for analysis.

Composite samples in 5.0' intervals were taken by Lovell Clay Products representative.

Lynac sampler was driven at 42.2' contact to determine the density of the gravel.

Casing *Blows*	*Penet-ration*	*Rotary Drilling*	*Remarks*
30/ R	0.3	@	42.2' to 42.5' - No Recovery
50/ R	0.2	@	42.5' to 42.7'

Elevation Reference Point: Iron pin at
Sta. 995+00
on ℄ of Median
Elevation 3133.30 ft.

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 476
Project No. I-90-8(23)U-2
Hole No. 3
Termini Billings
Date Taken May 12, 1965
Location 100' Lt. Sta. 992+00 on ℄ of median
Structure Lovell Clay Prospect Holes
Party Chief Cook
Others Green & Etzold

Miscellaneous Data
Depth of Hole 36.2 ft.
Rock
Wt. of Hammer 140#
Average Fall of Hammer 30"
Elev. of Ground Water. 30.6 ft.

Stratification			*Description of Materials Type, Color & Consistency*	*Casing*		*Rotary Drilling*
Elev.	*Depth*	*Legend*		*Blows*	*Penet-ration*	
3126.52 ft.			Brown silt			
			Brown silty sand			
	10.0		to brown sandy silt. Trace of silt clay.			
	16.0		Brown silty sand.			
	18.0		Brown silt clay. Moist at 19.0 ft.			
	24.0		Wet brownish grey sand.			
	25.0		Stiff brown clay.			
	35.2		Gravel.	40/50	1.0	@
	36.2		Bottomed hole in very tight gravel.			

Remarks

Hole was bored with 4" Iwan auger in 0.5' and 1.0' intervals, depending upon expansion of the material in the auger.

Samples in 1.0' intervals were bagged in Poly bags and were given to Yapuncich, Sanderson & Brown La for analysis.

Composite samples of 5.0' intervals were taken by Lovell Clay Products representative.

Lynac Sampler was driven at 35.2 ft. depth to deterdensity of gravel at contact.

40/50 1.0 @ 35.2' to 36.2'

Elevation Reference Point: Iron pin at Sta. 995+00 ℄ median

Elev. 3133.30 ft.

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 477 Project No. I-90-8(23)U-2 Hole No. 4
Termini BBillings Date Taken May 13, 1965
Location Sta. 996+00 on ℄ of N. E. Road. Structure Lovell Clay Prospect Holes
Party Chief Cook Others Green & Etzold

Miscellaneous Data	
Depth of Hole	23.5 ft.
Rock	
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water.	12.2 ft.

Stratification			Description of Materials Type, Color & Consistency
Elev.	Depth	Legend	
3115.4 ft.			Brown clayey silt.
	5.0		Brown silt clay.
	9.0		Brownish grey sand; wet.
	12.0		Dark brown clay.
	16.0		Very soft brown silty clay.
	18.0		Stiff brown clay.
	22.5		Gravel.
	23.5		Bottomed hole in dense gravel.

Remarks

Hole was bored with 4" Iwan auger in 0.5' and 1.0 ft. intervals, depending on the expansion of the material in the auger.

Samples in 1.0 ft. intervals were bagged in Poly bags and given to Yapuncich, Sanderson & Brown Lab for analysis.

Composite samples of 5.0 ft. intervals were taken for Lovell Clay Products.

Lynac Sampler was driven at 22.3' to determine density of gravel at contact.

Blows	Penetration	Rotary Drilling	
25/36	1.0	@	22.5' to 23.5'

Elevation Referenct Point: Iron Pin at Sta. 995+00 on ℄ median.

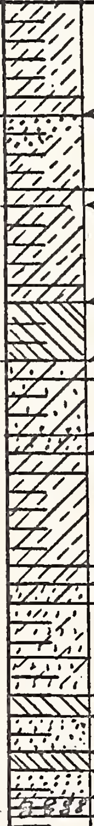
Elevation 3133.30 ft.

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 478 Project No. I-90-8(23) U-2 Hole No. 5
Termini Billings Date Taken May 13, 14, 1965
Location 115' Rt. Sta. 996+00 on ℄ Structure Lovell Clay Prospect Holes
Party Chief Cook s Green & Etzold

Miscellaneous Data
Depth of Hole 43.4 ft.
Rock
Wt. of Hammer 140#
Average Fall of Hammer 30"
Elev. of Ground Water 34.6 ft.



Stratification			*Description of Materi* *Type, Color & Co*y	*Casing*		*Rotary Drilling*
Elev.	*Depth*	*Legend*		*Blows*	*Penet-ration*	
3137.08 ft.			Brown sandy silt.			
	6.0		Brown silty sand to sandy silt.			
	11.0		Brown silty clay.			
	16.0		Stiff dark clay.			
	19.0		Sandy clay.			
	23.0		Clayey sand strata.			
	24.0		Moist silty clay.			
	31.0		Moist sandy clay.	50/50	0.9	@
	32.0		Moist silty sand.			
	37.0		Dark clay.			
	38.0		Silty brown sand.			
	40.0		Dark clay.			
	41.0		Silty brown sand.			
	42.5		Sandy gravel.			
	43.4		Bottomed hole in dense sandy gravel.			

Remarks

Hole was bored with 4" Iwan auger in intervals of 0.5' and 1.0' dependent on expansion of materia in auger.

Samples in 1.0 ft. intervals were bagged in Poly ba and were given to Yapuncich, Sanderson & Brown Lab for analysis.

Composite samples in 5.0 ft. intervals were taken by Lovell Clay Products representative.

Lynac Sampler was driven at 42.5 ft. to determine density of the gravel.

50/50 0.9 @ 42.5' to 43.4'

Elevation Reference Point: Iron pin at Sta. 995+
℄ median

Elev. 3133.30 ft.

BM	BS	HI	FS	CE
3133.30	6.5	3139.80	4.75	3135.05
	6.24	3141.29	5.10	3136.19
	6.10	3142.29	5.21	3137.08

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA

LAB NO. 6806

ANALYSIS OF SAMPLES FROM HOLE NO. 1

PROJECT NO. I-90-8-23
LOVELL CLAY PRODUCTS PROPERTY

COMPOSITE INTERVAL, FT.	SAND CONTENT, % (1)	LIQUID LIMIT % MOISTURE (2)	PLASTIC LIMIT % MOISTURE (3)	PLASTICITY INDEX (4)	SOIL TYPE
0.0-1.0	16.2	38.4	19.2	19.2	Clay
1.0-6.0	19.9	27.2	17.2	10.0	Silty Clay
6.0-11.0	19.9	27.3	16.5	10.8	Silty Clay
11.0-15.0	18.4	26.4	17.1	9.3	Silt
15.0-20.0	27.6	25.0	17.8	7.2	Silt
20.0-25.0	13.5	33.7	17.6	15.1	Clay
25.0-30.0	21.2	32.7	18.0	14.7	Clay
30.0-38.0	8.3	42.5	21.4	21.1	Clay

(1) Sand remaining on 200 mesh screen. Sand went through 40 mesh screen.

(2) AASHO Method T-89

(3) AASHO Method T-90

(4) AASHO Method T-91

Liquid limit, plastic limit & plasticity index determinations made by Montana Highway Department Materials Laboratory, Billings, Montana.

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA
LAB NO. 6806

ANALYSIS OF SAMPLES FROM HOLE NO. 2

PROJECT NO. I-90-8-23
LOVELL CLAY PRODUCTS PROPERTY

COMPOSITE INTERVAL, FT.	SAND CONTENT, % (1)	LIQUID LIMIT % MOISTURE (2)	PLASTIC LIMIT % MOISTURE (3)	PLASTICITY INDEX (4)	SOIL TYPE
0-5	26.0	29.3	17.3	12.0	Silty Clay
5-10	31.5	25.5	14.6	11.0	Silty Clay
10-15	16.1	26.2	15.0	11.2	Silty Clay
15-20	13.1	28.9	19.3	9.6	Silt
20-25	18.7	30.0	16.4	13.6	Clay
25-30	18.1	32.1	18.4	15.7	Clay
30-35	11.6	35.7	15.5	20.3	Clay
35-42	13.4	37.8	20.4	17.4	Clay

(1) Sand remaining on 200 mesh screen. Sand went through 40 mesh screen.

(2) AASHO Method T-89

(3) AASHO Method T-90

(4) AASHO Method T-91

Liquid limit, plastic limit & plasticity index determinations made by Montana Highway Department Materials Laboratory, Billings, Montana

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA
LAB NO. 6806

ANALYSIS OF SAMPLES FROM HOLE NO. 3

PROJECT NO. I-90-8-23
LOVELL CLAY PRODUCTS PROPERTY

COMPOSITE INTERVAL, FT.	SAND CONTENT, % (1)	LIQUID LIMIT % MOISTURE (2)	PLASTIC LIMIT % MOISTURE (3)	PLASTICITY INDEX	SOIL TYPE
0-5	26.5	25.8	15.8	10.1	Silt
5-10	30.7	25.5	14.6	10.9	Silty Clay
10-15	12.7	29.5	15.6	13.9	Clay
15-20	28.8	25.1	17.3	7.8	Silt
20-25	19.7	27.6	16.9	10.8	Silty Clay
25-30	4.2	52.1	21.0	31.1	Clay
30-35	8.6	34.8	18.6	16.2	Clay

(1) Sand remaining on 200 mesh screen. Sand went through 40 mesh screen.

(2) AASHO Method T-89

(3) AASHO Method T-90

(4) AASHO Method T-91

Liquid limit, plastic limit & plasticity index determinations made by Montana Highway Department Materials Laboratory, Billings, Montana.

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA
LAB NO. 6806

ANALYSIS OF SAMPLES FROM HOLE NO. 4

PROJECT NO. I-90-8-23
LOVELL CLAY PRODUCTS PROPERTY

COMPOSITE INTERVAL, FT.	SAND (1) CONTENT, %	LIQUID (2) LIMIT % MOISTURE	PLASTIC (3) LIMIT % MOISTURE	PLASTICITY INDEX	SOIL TYPE
0-5	18.3	35.5	16.4	19.2	Clay
5-10	19.9	32.4	16.5	15.9	Clay
10-15	15.7	46.0	19.6	27.4	Clay
15-22.5	8.7	42.9	18.8	24.1	Clay

(1) Sand remaining on 200 mesh screen. Sand went through 40 mesh screen.

(2) AASHO Method T-89

(3) AASHO Method T-90

(4) AASHO Method T-91

Liquid limit, plastic limit & plasticity index determinations made by Montana Highway Department Materials Laboratory, Billings, Montana

YAPUNCICH, SANDERSON & BROWN LABORATORIES
BILLINGS, MONTANA

LAB NO. 6806

ANALYSIS OF SAMPLES FROM HOLE NO. 5

PROJECT NO. I-90-8-23
LOVELL CLAY PRODUCTS PROPERTY

COMPOSITE INTERVAL, FT.	SAND CONTENT, % (1)	LIQUID LIMIT % MOISTURE (2)	PLASTIC LIMIT % MOISTURE (3)	PLASTICITY INDEX (4)	SOIL TYPE
0-5	16.3	38.0	19.6	18.4	Clay
5-10	28.1	30.0	18.5	11.5	Silty Clay
10-15	15.0	32.3	19.1	13.2	Clay
15-20	15.4	30.3	16.9	13.4	Clay
20-25	20.6	29.9	17.0	12.9	Clay
25-30	16.2	35.6	17.2	18.4	Clay
30-35	30.6	27.3	17.5	9.8	Silt
35-42.5	15.0	38.0	20.0	18.2	Clay

(1) Sand remaining on 200 mesh screen. Sand went through 40 mesh screen.

(2) AASHO Method T-89

(3) AASHO Method T-90

(4) AASHO Method T-91

Liquid limit, plastic limit & plasticity index determinations made by Montana Highway Department Materials Laboratory, Billings, Montana

FORM NO. 159

STATE HIGHWAY COMMISSION OF MONTANA

SHEET 1 OF 2 SHEETS

PLANS DIV.____ GRADES____ AREAS____ VOLUMES MASS DATA____

LOCATION Lovell Clay Products Co., Inc DATE____ PROJ. NO. I-90-8-23

STATIONS 7.44 CH.____ DISTANCE 744' CH.____ GRADES____ CH.____

VERT.____ CH.____ AREAS____ CH.____ VOL.____ CH.____ MASS____

GRADES & V. C.	V. C. CORR.	CORR. ELEV. ...... ELEV.	STATIONS	DISTANCE	AREAS IN SQUARE FEET				VOLUMES IN CUBIC YARDS							
					CUT		FILL		EXCAVATION			EMB		MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	CLASSIFICATION	ROCK	TOTAL	ACTUAL	EMB +	CUT +	FILL —	Σ
					Cu. Yds. of Clay Below Water Level											
			991+17		0											
				33		690					422					
			+50		690											
				50		2236					2070					
			992		1546											
				50		3358					3109					
			+50		1812											
				50		3900					3611					
			993		2088											
				50		4443					4114					
			+50		2355											
				50		4977					4608					
			994		2622											
				50		5603					5188					
			+50		2981											
				50		6311					5844					
			995		3330											
				50		6918					6406					
			+50		3588											
				50		7461					6908					
			996		3873											
				21		7838					3048					
			+21		3965											
				29		7507					4032					
			+50		3542											
				50		6228					5767					
			997		2686											
				34		4802					3023					
			+34		2116											
				21		3892					1514					
			+55		1776											
				45		2797					2331					
			998		1021											
				50		1214					1124					
			+50		193											
				11		193					39					
			+61		0											
				744	40,184	80,368					63,158 CU. YDS.					

NOTE: Survey and calculations by the Montana State Highway Department, Billings, Montana.

FORM NO. 159

STATE HIGHWAY COMMISSION OF MONTANA

SHEET 2 OF 2 SHEETS

PLANS DIV____ GRADES____ AREAS____ VOLUMES MASS DATA____

LOCATION Lovell Clay Products Co., Inc. DATE ____ PROJ. NO. I-90-8-23

STATIONS 7.44 CH.____ DISTANCE 744' CH.____ GRADES____ CH.____

VERT.____ CH.____ AREAS____ CH.____ VOL.____ CH.____ MASS____

GRADES & V. C.	V. C. CORR.	CORR. ELEV. ······ ELEV.	STATIONS	DISTANCE	AREAS IN SQUARE FEET				VOLUMES IN CUBIC YARDS							
					CUT		FILL		EXCAVATION			EMB		MASS CURVE DATA		
					AREA	DOUBLE AREA	AREA	DOUBLE AREA	CLASSIFICATION	ROCK	TOTAL	ACTUAL	EMB +	CUT +	FILL —	Σ
					Cu. Yds. of Clay Above Water Level											
			991+17		0											
				33		1875					1146					
			+50		1875											
				50		6039					5592					
			992		4164											
				50		9251					8566					
			+50		5087											
				50		11182					10354					
			993		6095											
				50		13235					12255					
			+50		7140											
				50		14298					13239					
			994		7158											
				50		14969					13860					
			+50		7811											
				50		16135					14940					
			995		8324											
				50		17191					15918					
			+50		8867											
				50		18584					17207					
			996		9717											
				21		19778					7691					
			+21		10061											
				29		18568					9972					
			+50		8507											
				50		14582					13502					
			997		6075											
				34		10460					6586					
			+34		4385											
				21		8367					3254					
			+55		3982											
				45		6076					5063					
			998		2094											
				50		2463					2281					
			+50		369											
				11		369					75					
			+61		0											
			NOTE:	~~Survey & calculations by Montana State Highway Department, Billings, Montana~~												
			744	744	101,711	203,422					161,501 CU. YDS.					

CHAMPION CLASP No. 55
6 X 9

WESTERN LITHO-PRINT, INC., BILLINGS, MONTANA